<u>Reviewer Comments on 5-Year Midterm Report on Flathead Lake Fisheries Co-Management</u>

The following pages contain the expert reviews of the 5-Year Midterm Report on Flathead Lake Fisheries Co-Management. These reviews are assembled as an addendum to the five-year midterm review report and will be provided to each Flathead Reservation Fish and Wildlife Board member and available to any other interested party on request. This addendum will be a living document and will be added to as the remaining two reviews are received. The following pages contain the expert reviews received by November 1, 2006.

Reviewer Number 1.

General Comments:

This synthesis obviously represents a lot of work on the lake and associated fisheries. You guys are to be complimented on the efforts you've made. It's particularly encouraging to see a collaborative process that is producing a continued flow of information. I appreciated the focused presentation of the results making my task of reading and comprehending the mass of information relatively easy. I do think it's important to provide a little more detail on the sampling methods and to carefully evaluate the utility of your metrics with traditional statistical methods. Otherwise it seems you risk doing a lot of work for information with little value. I found some of the wording confusing and sometimes contradictory. It may be mostly semantics but some consistency the wording might help my level of comfort in the results. In general I think the metrics are telling you something. I agree that the weight of information indicates that lake trout are not declining, but given the conflicting information I am not comfortable that they are not increasing slowly either. Based on the redd count data and my understanding of the quality of that work I am also comfortable that the bull trout populations are not collapsing, but I am not at all optimistic about their future. I hope these comments are useful. I'll be happy to answer questions or provide details where I can.

Thanks for the opportunity to see what you're up to.

Specific Comments:

Page 11. 1st paragraph starting "in summary.."
The suggestion is that trends are not measurable criteria. Concluding whether there is or isn't a trend should be measurable if the data are collected appropriately. It seems particularly important to keep that in mind in the design of the monitoring work to determine whether or not a trend can be detected…. If not perhaps the work is a waste of time and money.

P. 12
".. the secure level.." It isn't clear what the secure level has to do with the trend. Depending on the time scale that you use to analyze the redd counts the population could be declining, or even increasing. Is there some further logic to help here? Given that the populations appear cyclic it would seem that you need to go at least two cycles to feel like you have a hint of what the long term picture might be.

Figure 2.
Details about the effort would help here. Is this a standardized effort? Can you provide a measure of the variation in catches to see if these data are useful?

Page 13
Figure 3. Not sure what the red bars are. Again some measure of variation is needed to see whether this is useful. Cyclic pattern, but long term suggestion sure looks like decline. It's not clear what you mean by no consistent trend in abundance. Based on figure 1 data (which look a little more variable than these) you concluded the trend was stable. Isn't stable consistent?

P. 15
2nd paragraph. It isn't clear to me why you conclude cutthroat are stable. The paragraph above suggests they are declining and the other measures are concluded to be not useful.

P. 16.
Staples et al. It would be interesting to know how the vital rates used for this modeling were determined. It appears that you don't have much data on these actual rates, so how good can the results of this analysis be? Are they derived somehow from this population or are they summaries from the literature. Later you do some demographic analysis that uses a slightly different approach. It would seem that a well documented lake trout demographic model is important to several of the questions you want to explore.

P17. Alternate interpretation
Do you have a reference for the bull trout lake trout coexistence. I would love to see that work. Does the pattern hold with Mysis as well? E.g. bull trout and lake trout coexisted for a long time in Priest Lake, but once Mysis became established the lake trout population exploded and bull trout declined.

It ***is*** logical to conclude that natal habitat conditions represent an interaction with a lake trout effect. Presumably lake trout and bull trout interact directly outside of the natal tributaries. But if survival is poor in the natal habitat that population is likely to have less resilience and be more vulnerable to predation or competition outside that habitat. This is a particularly troublesome idea because general trends associated with climate change are not positive for bull trout tributary habitats while they may be irrelevant for lake trout.

P. 18. Paragraph starting "We conclude…"
I'm confused, earlier you concluded that bull trout were stable, here you indicate you observed downward trends. Are you implying a different time frame for a different purpose?

p. 19
Figures 8 and 9. same questions about the methods as before. Some measure of variance would help.

P19-20
Figure 10. I would disagree with the assessment that the mysis data preclude any determination of a trend given what's presented. This is the only data with some measure of sampling variance and, assuming the data are actually correct, there are several periods of change that would be clearly significant. I assume that you are looking for a recent trend of a given direction (i.e.. up) that tells you something might be happening with lake trout. If that's the case your choice of time is important and wording is important. Mysids clearly appear to be less abundant than they were following establishment and there appears to be some decline since 1997 when both bull trout and lake trout looked like they might be increasing a bit…. Is the point that you don't have a big increase in the time frame you would expect it? Later you suggest that mysis are stable so lake trout must be stable… again a little care with the wording would help folks like

me. The data either are or are not useful for your evaluation. In my view, if variability precludes determining a trend then you cannot also conclude they are stable.

I haven't had the opportunity to read Beauchamp 2006, but I'm having trouble rationalizing the conclusion that mysids are limited by the prey base because there are plenty of zooplankton. The earlier report concluded that mysis strip zooplankton from the lake. Haven't there been observations of important changes in the zooplankton that were presumed important for kokanee. Are mysids generalist predators or do they use select prey? Have you compared the mysis densities or production in Flathead with other systems?

P. 21-22.
I'm having a hard time rationalizing figures 12 and figure 13. How can lake trout harvest and angler days be relatively stable when lake trout catch rate has gone almost 3 fold in the same period. Are most fish released? If so need to clarify.

P. 22…".. it is reasonable to expect that length of fish was shorter…"
Lake trout condition and growth changed dramatically in Priest Lake after kokanee collapsed there as well (Bowles et al. AFS Symposium 9: 65-74).

P. 24. I tried to estimate mortality using a catch curve reading the numbers off the graphs. I got 0.21, but I might not have used the same time period. How did you estimate mortality?

P. 25. 1st paragraph. Not clear to me why you would assume either recruitment or annual mortality to be constant, Is constant recruitment apparent elsewhere? I do think you could assume the variation is small enough to use a catch curve analysis. I get 0.19 for the data on figure 17.

P. 27. Figure 21. The figure isn't labeled completely. Are there a number of lines for each year fit through the data? The different style of points suggests that there might be changes (e.g. all the yellow points are above the line, most of the blue + are above). Any response here might be really subtle so care in the analysis seems important.

P 27. Figure 22. Can you compare the condition of lake trout to other lakes with mysis and not kokanee. Bowles cited above might be useful.

P. 29 Figure 23-24. If you don't have a hypothesis why develop the data? There is reason to expect earlier age at maturity with high mortality and that has been demonstrated in many stocks of fish. So….if growth is not changing a lot in the same time frame or even declining as you think, longer length at maturity would equate to later age at maturity…… and by inference declining or low mortality….wouldn't it??

Although I got a little grouchy about the lack of measures of variability in any of the metrics and the inconsistent wording I agree that the weight of evidence indicates lake trout are not declining.

Section IV

I read through this section very quickly, but it struck me that it would be a relatively simple process to model lake trout population dynamics and consumption simultaneously to explore the relative sensitivity of prey consumption to exploitation and a range of assumptions about resilience in the population. You've made some foray into both demographic models with Staples, and bioenergetic models with Beauchamp so the foundation seems like it's already there. Why not build on that experience and information rather than create something new. It should be relatively straightforward to incorporate compensatory functions into the models that would be more direct and that would allow direct evaluation of fishing on lake trout and the potential influence on bull trout or other species. It is possible to have a substantial influence on prey consumption by just increasing the mortality on a population, without collapsing it (see Rieman and Beamesderfer NAJFM 1990 10(2):228-241). It appears that bull trout have only been a small component of the diet of larger lake trout so this might actually turn out to be important. It might also be useful to look at Rieman and Myers 1991. Costs, benefits, and risks of salmonid predators in kokanee waters. IDFG job completion report F-73-R-13.

Questions for Reviewers

1. This is difficult to tell. Because you don't provide measures of variability to consider sampling error and inherent variability in the data you can't really evaluate the relative utility of most of the metrics. At face value some look ok, and given the weight of evidence I think your conclusions are probably valid. It's tough to know how much the system would have to change though before you could pick it up.

2. I think you've got the right things, but details of the methods and details in the results would help figure out whether they can-should be refined.

3. It makes sense to me that a population with lower quality habitat in the natal environment would be less resilient. Unless there is some reason to believe that these fish migrate earlier or are somehow more vulnerable to lake trout what other explanation exists?

4. This is obviously an impossible question to answer…… but…… I think you could be in deep trouble. Climate change is happening and in your part of the world (and throughout the northern interior west) there is clear evidence of warming, earlier melt, etc. The general projections are for warmer, wetter winters, and dryer warmer summers. That translates into lower base flows, warmer streams, reduced spring peak flows (often important for access to habitat in the Pend Oreille), and increased frequency of rain-on-snow and winter scour events. It's already apparent in some systems and we believe there could be range contraction already going on for bull trout. In our analyses so far the Flathead appears to be one of the more resilient areas to these effects because of the topographic relief but it will not be immune. Your data suggest that the bull trout populations are depressed from historic numbers. Given that they are not growing when densities are low in the tributaries, it is logical to conclude that they have very little resilience left… i.e. they are not likely to be able to absorb much of an increase in mortality or decline in productivity. At the same time climate change may have little influence on lake trout at least not initially in deep lakes (It might be worth checking the literature on this idea, since I think there has been some work on it). So I would anticipate things are going to get a lot tougher for bull

trout and I would not be optimistic about a seriously depressed population that is not growing….. It may not be just lake trout, but they probably won't help.

For a great summary see Mote, P. W., A. F. Hamlet, M. P. Clark, and D. P. Lettenmaier. 2005. Declining mountain snowpack in western north america. Bulletin of the American Meteorological Society. (January):39-49.

5. See Bowles et al. referenced above. Might be worth talking with the Idaho guys, but I think lake trout growth declined substantially and I would expect it to at older ages as they transition from fish to mysids. Lake trout live a long time so the process takes a long time to be evident.

6. See Bowles et al.

7. Don't know that one.

8. See my earlier point in comments above….. **do I win**?

9. Some Great Lakes biologists can probably help, I'm guessing Mike Hansen has the answer. But unless there is something else likely to suppress lake trout if they dropped to low levels, I would guess they would not collapse.

10. Not sure, but I wouldn't expect it to be bad for bull trout. Since they are relatively large when they hit the lake and since they seem to use a lot of mysis it might actually be positive.

11. I have a hard time believing that lake trout have a really sharply domed stock recruitment function…… but it's been a long time since I've paid much attention to those things. What can you learn from Yellowstone where they're trying to hammer lake trout? What do you know from the literature from other systems. There has been a lot of work on exploited lake trout populations. What does that suggest?

Reviewer Number 2.

Phase I of the Five-Year Review of the Flathead Lake and River Fisheries Co-Management Plan Technical Fisheries Data Section

Introduction

I was asked to participate as an external evaluator for *Phase I of the Five-Year Review of the Flathead Lake and River Fisheries Co-Management Plan*. I participated in the first panel on Flathead Lake, so I found this review to be very interesting! Thank you for the opportunity to participate! My overall opinion of your review document is that you nicely summarized a large amount of information in a small package. In this section of my response, I give my overall impression of each section of the summary document, and follow in the next section with my responses to the list of specific questions listed at the end of the review document.

General Opinion

I. Background – The opening section of the plan provides an understandable overview of the plan and purpose of the 5-year review. The plan was obviously a product of extensive investments by many people. However, the review document was difficult to interpret without the executive summary document, which seemed much clearer about the management objectives (i.e. measurable). For clarity, the review document could have been clearer if it stood alone better, without the need for supplemental documents. This is not a severe problem, but just required more study than was necessary.

II. Cutthroat and Bull Trout – The first technical section of the plan provides data on trends in abundance of cutthroat trout and bull trout. Many of the abundance indices are accompanied by a graph that illustrates the abundance index through time. However, some abundance indices are not accompanied by a graph, which precludes their review. For example, angler catches of bull trout are not accompanied by a graph, but rather, are presented as a range of values, which prevents our review. Similarly, all but one index of cutthroat trout abundance are presented without a graph of data. Such indices of abundance cannot therefore be considered part of our review. In any case, this section clearly shows that both bull trout and cutthroat trout both declined substantially from the 1980s to the present decade. Interestingly, the conclusion reached by authors of the summary report is that abundance of both species is stable in the present decade, though they acknowledge in the next section not knowing if bull trout will continue to decline. My opinion of this conclusion is conveyed below, in my responses to questions.

III. Lake Trout – The second technical section of the plan provides data on trends in various statistics related to lake trout abundance and their interaction with other species. The organization of this section is more confusing than the previous section, because trends in lake trout abundance are mixed with trends in abundance of other species. The summary of information would have been clearer if trends in abundance of lake trout and other species were summarized first (as for bull trout and cutthroat trout), and then interactions among species were summarized in a follow-up synthesis. In addition, the presentation of *Mysis* abundance belongs in its own section, rather than in the lake trout section. In any case, this section conveys a compelling view that lake trout abundance is stable in the present decade, despite attempts to remove lake trout at a rate that would cause a significant decline in abundance. The conclusion reached by authors of the summary report is that lake trout acted to reduce bull trout abundance in the lake, through some unknown mode of interaction. Technical issues include:

- The age structure shown in Figure 16 is derived from non-randomly sub-sampled otolith ages, which is incorrect. Whenever ages are non-randomly sub-sampled, an age-length key *must* be used to estimate the age structure of the sample from which the age structures were sub-sampled. Technically, an age-length key must also be used when estimating mean length at age from a non-random sub-sample of ages, but the bias of using the sub-sample is not great, in my experience.

- Age structures shown in Figures 17–20 for 2002–2005 seem to be based on age-length keys, though the description of the method used is not clear enough for me to understand. In any case, the mortality rates shown in the four years are remarkably similar, which suggests a constant mortality rate. However, I do not understand why ages above age-15 were excluded from the catch curve! In addition, I cannot tell if the mortality rate indicated on the figures is the instantaneous total mortality rate Z or the total annual mortality rate A.

- Maturity is best judged as the age, not length, at which 50% of individuals are mature, but you present only data on length at 50% maturity (despite the title *increased age at maturity* for the sub-section). You seem puzzled by an increasing trend in maturity, but age at maturity should increase with population density, because growth declines with increased density, so fish take longer to reach maturity. If older = longer, then the trend is expected!

IV. Future Lake Trout Abundance – This section provides a summary of modeling efforts to estimate how the lake trout population in Flathead Lake will likely respond to higher rates of harvest. The modeling approach is admittedly simplistic, mostly derived from spreadsheet calculations based on observations and estimates presented in the previous sections of the report. The modeling also attempts to anticipate compensatory responses in recruitment, if lake trout abundance declines. However, this section was very difficult to follow, mostly because the text was not clear about what was done. Therefore, my conclusions may be off-base, if my understanding is wrong. In any case, this section conveys the *impression* (not stated) that the lake trout population will likely compensate for increased mortality by increasing recruitment. I cannot accept such a conclusion (if such a conclusion was intended), based on repeated observations of recruitment over-fishing throughout the species' range (Healey 1978) and particularly the World's largest lake trout populations (Hansen 1999). Technical issues include:

- On page 35, the authors state that "The age at which female lake trout reach full maturity has changed from age 6 to age 11 between 1997 and 2005 (Figure 31)." However, the figure shows only *length* at 50% maturity, so I cannot verify the accuracy of the statement.

- In Table 2, you use a natural mortality rate of M = 0.068 for lake trout of ages 7–31, which seems much too low, based on my prior experience with lake trout. For example, we use M = 0.1649 for our lake trout modeling in eastern Lake Superior, based on Pauly's equation, which relies on a relationship between instantaneous natural mortality (M), asymptotic length (L_∞ = cm), instantaneous growth rate (K), and mean annual air temperature (T = C). For otolith data on 153 individual fish included in the report by Stafford (2006), I estimated Von Bertalanffy growth model parameters for the lake trout population in Flathead Lake as (see output attached): L_∞ = 902.823 mm, K = 0.070050062/year, t_0 = –2.069325536 years, and ε = multiplicative. Based on these estimates of L_∞ and K, and a mean annual air temperature for Kalispell of $T = 10^{o}$C (a guess), I think you should be using a value of M = 0.143.

- In Table 2, the sum of M and F should be 0.32 (assuming the number on the figure is Z, rather than A) for fish of ages 7–15. However, the sum of M and F is less than 0.32 for all ages except age 5, which wasn't even included in the catch curve estimate. I must have missed something in the description of your methods, but I thought you relied on your catch-curve estimate for values of mortality in this table.

Responses to Specific Questions

General Trends (Sections II and III):

1. Of the population trend indicators described above, which do you think are the most reliable and informative?

- For bull trout, redd counts, gill-net catch rates, and stream electrofishing catch rates indicate similar patterns of decline from the 1980s to the present. In conclusion, all sampling indices seem to provide reasonable indices of bull trout density and abundance at both adult (redd counts and gill-net catch rates) and juvenile (stream electrofishing catch rates) life stages.
- For cutthroat trout, data were shown only for gill-netting, and the trend was similar to that of bull trout. Evidently, none of the other indices seem to provide reasonable indices of population trends, likely because the species is so rare in the system, though data were not provided for me to judge this conclusion for myself. In conclusion, I cannot conclude anything about the reliability of methods used for indexing cutthroat trout population density, because data were only shown for one method of sampling (gill netting).
- For lake trout, two gill-net surveys provide similar patterns of lake trout catch rates, so seem concordant. The gill nets used for the fall survey seem to be of a wide enough range of mesh sizes to index the entire range of lake trout sizes, but the mesh sizes of nets used for the spring index netting are generally too small (i.e. largest mesh is 4.0-inch stretch-measure). In conclusion, spring and fall gill netting seem to reliably index lake trout population density and abundance, but the spring index netting should be enhanced by adding more panels of large meshes.

2. It has not been easy to demonstrate trends in lake trout abundance. Are there other population trend indicators you think are more useful than the ones we have used?

- Sampling methods for lake trout generally rely on gill nets, trawling, and angling, because lake trout are vulnerable to sampling in all of these gears. Large-mesh gill nets are used in the Great Lakes to index adult lake trout density in spring, summer, or autumn, but catch rates in autumn can be misleading if the gear is set in spawning areas where catch rates are nearly always high (so are not informative of relative abundance). Small-mesh gill nets are also used in the Great Lakes to index sub-adult lake trout density in summer. Last, trawls are used in Lake Superior to index juvenile lake trout density in spring. In small inland lakes, graded-mesh gill nets are mostly used to index lake trout abundance in spring (e.g. Ontario). Each sampling method returns an estimate of relative abundance (catch per unit of effort) and related biological statistics derived from length, weight, and age (size structure, body condition, growth, and mortality). In conclusion, I do not see any "holes" in your use of sampling gears or biological statistics that would likely increase your understanding of fish population or community dynamics.

Factors controlling bull trout abundance (Section III A.):

3. Coal Creek has been an anomaly among spawning tributaries. Which explanation do you think most reasonably explains the differential response of bull trout in Coal and Big creeks; differential response to in-stream habitat conditions, or differential mortality in Flathead Lake, or a combination of the two?

- The most reasonable explanation for a decline in redds in Coal Creek that was not found in other spawning streams (e.g. Big Creek) is that spawning habitat in Coal Creek declined in quality or quantity. I assume that bull trout return to the same stream where they were born, so redd counts in Coal Creek reflect a decline in the number of juvenile bull trout produced previously. However, if bull trout do not return to the same stream where they were born, then a change in habitat quality or quantity in Coal Creek cannot reasonably explain the decline in redds in that stream. In addition, as you point out in your review, the alternative hypothesis (i.e. that juvenile bull trout from Coal Creek suffer greater in-lake mortality than those from other streams) is difficult to sustain on logical grounds.

4. While bull trout declined substantially in the past two decades, we think they are now stable. This raises the importance of knowing whether this condition can persist well into the future? What do you think is the likelihood that lake trout will completely eliminate bull trout in Flathead Lake in the long term?

- The conclusion that bull trout are now *stable* is tenuous, when viewed in the context of prior abundance in the 1980s (Figure 1). In Figure 1, redd counts exhibit a long-term declining oscillation that could spell the end of the population in Flathead Lake if a 3rd (lower) oscillation occurs in the next decade that mimics the decline from the 1st oscillation in the 1980s (high) to the 2nd oscillation in the present (intermediate). Randall Peterman argued that fishery managers should assume the worse (i.e. that a population is declining) until proven otherwise, because: (1) trends in fish abundance are fraught with large measurement and process errors; (2) Type-II errors are highly likely; and (3) consequences of Type-II errors are more catastrophic than consequences of Type-I errors. I think his advice is prudent when dealing with a bull trout population that is clearly in a state of long-term decline.

Growth of lake trout (Section III B.):

5. We are surprised by the large changes in growth of lake trout and are concerned about accuracy in aging. Have you observed similar changes in growth rate of lake trout over a fifteen year period to what we have seen in Flathead Lake?

- Growth rate can be indexed in many ways, but we observed a 10-cm decline in mean length at age 7 of lake trout over a 20-year period from the 1970s through the 1990s, in some areas of Lake Superior where population density increased the most.

Therefore, the decline in size at age of lake trout in Flathead Lake from pre-*Mysis* to post-*Mysis* years seems reasonable to me.

6. We are also surprised by the very low condition factor of these lake trout. Do you know of examples where lake trout (>8 years old) in communities of *Mysis*, yellow perch and coregonids have higher condition factors than the Flathead population?

- We do not measure body condition of lake trout as part of routine monitoring in Lake Superior, so I have no basis of reference for this question. However, low body condition is consistent with slow growth observed in the post-*Mysis* period in Flathead Lake. Similarly, body condition of lake trout declined sharply in Priest Lake, Idaho, after Kokanee collapsed and were replaced by *Mysis* in lake trout diets. The post-*Mysis* weight-length relation for Priest Lake (Bowles et al. 1991; Figure 6) looks similar to the weight-length relation depicted in your summary (Figure 21). I suspect that lake trout populations in some Ontario lakes exhibit low body condition, when lake trout live in lakes without a viable fish prey, but Nigel is more qualified to address this question.

7. We have been working with length at age rather than measuring annual increments, meaning that growth within the year of capture is important for comparison. When during the year is the lake trout annulus formed?

- I assume that annuli form during winter, when growth is slow. Therefore, fish caught in spring often show little growth on the edge of otoliths beyond the last annulus, whereas fish caught in summer or autumn often show substantial growth on the edge of otoliths beyond the last annulus. However, to confirm when the annulus is formed by lake trout in Flathead Lake, you should probably complete a study of edge formation from fish caught throughout the year (i.e. marginal increment analysis; Campana 2001).

8. There should be a lottery prize for this question. Can you provide an explanation for the increase in length at maturity, knowing that growth rate has decreased over the time period?

- What is the prize for the most plausible answer? Alternatively, maybe you should give a prize for the most implausible answer, because the implausible sometimes comes true in ecological systems! Frankly, I am more comfortable thinking about age at maturity, because I assume that length at maturity is relatively constant, and therefore, that age at maturity responds to density-dependent changes in growth. However, you show only length at maturity, which increases through time, presumably as density increases and growth decreases. If you have data to estimate age at maturity, then you should do so, to clear up the answer to this question. In the absence of age at maturity, then I can only speculate that increased length at maturity is likely correlated to increased age at maturity, which is consistent with density-dependent compensatory responses: increased population density ➔ decreased body condition ➔ decreased growth ➔ increased age (and size?) at maturity. In short, I do not understand why you think this trend is surprising.

Uncertainty about harvest of lake trout (Section IV):

9. While managers are striving to reduce lake trout, the fact remains that lake trout provide the bulk of angling opportunity in Flathead Lake. There is a concern by some that we might over-shoot our lake trout exploitation target. If so, what are the likely ramifications to the future lake trout population?

- We have a long history of over-fishing lake trout in North America (Healey 1978), including the largest populations for the species in the Great Lakes (Hansen 1999). Consequently, the likely outcome of over-shooting your lake trout exploitation target is a decline in lake trout density that could ultimately lead to recruitment over-fishing and stock collapse. In a recent age-structured simulation modeling exercise for lake trout in eastern Lake Superior, we found that: (1) mean abundance began to decline at a fishing mortality rate of F = 0.20 (A = 42%) for the commercial fishery and F = 0.29 (A = 47%) for the recreational fishery; and (2) the risk of extinction began to increase above zero at a fishing mortality rate of F = 0.27 (A = 46%) for the commercial fishery and 0.33 (A = 49%) for the recreational fishery. If the lake trout population in Flathead Lake is similar to the lake trout population in eastern Lake Superior, then you may see a population decline or extinction at similar levels of angling fishing mortality. The real difficulty of this comparison is that sea lampreys exert mortality on lake trout in Lake Superior, but not in Flathead Lake. To enable a more informed answer to this question, you should undertake a modeling exercise that relies on a *stochastic* age-structured model, rather than a *deterministic* age-structured model. Such an approach will enable you to weigh the likelihoods of different management strategies.

10. There is also concern that a reduction in lake trout will cause an increase in *Mysis.* If so what secondary ecosystem effects do you anticipate?

- This question is beyond my expertise and experience, but seems to be aimed at the possibility that a reduction in lake trout predation on *Mysis* could cause an unforeseen trophic cascade. If true, then such a cascade should be evident in Lake Pend Oreille, where *Mysis* densities are an order of magnitude higher than in Flathead Lake. However, my discussions with Melo Maiolie, the lead IDFG fishery researcher on Lake Pend Oreille, do not suggest that *Mysis* are negatively affecting any other members of the aquatic community, directly or indirectly. In conclusion, I am skeptical that *Mysis* could cause problems elsewhere in the fish community, but I come from the Great Lakes where *Mysis* are generally perceived in a very favorable light.

11. Based on the information in the summary, do you think we may be on the right side of the peak in the stock/recruitment curve such that a reduction in the lake trout population could increase rather than decrease recruitment?

- I cannot directly compare your estimates of lake trout catch/effort because your spring assessment gill nets rely on a graded series of small meshes (1.5-inch, 2-inch, 2.5-inch, 3-inch, and 4-inch), whereas spring assessment gill nets in Lake Superior rely on a single large mesh (4.5-inch). Nevertheless, your aggregate catch rates (catch/net) ranged 1.3–2.1 fish per net during 1996–2005. Stock-recruit relations for wild lake trout in Michigan waters of Lake Superior peak at 45–726 age-8 and older lake trout per net-night, with right-hand limbs at even higher densities (recruitment was indexed as numbers of age-7 lake trout; Richards et al. 2004). A net-night in assessment fisheries on Lake Superior is defined as a kilometer of net soaked for one night, so I multiplied your range of catch/net (1.3–2.1 fish/net) by 26.25 (1000/38.1) to convert your catch rates into similar units as ours in Lake Superior. Based on this conversion, your catch rates (34.1–55.1 fish/net-night), if all of the catches occurred in the 4-inch panel (the closest mesh size to that used in Lake Superior) would just approach the peak of our stock-recruit relations in one part of eastern Lake Superior (with the most limited area of lake trout habitat) and would still require much higher densities to be on the right-hand limb of the stock-recruit curve. In conclusion, I see no evidence that your lake trout population is on the right-hand limb of a plausible stock-recruit curve.

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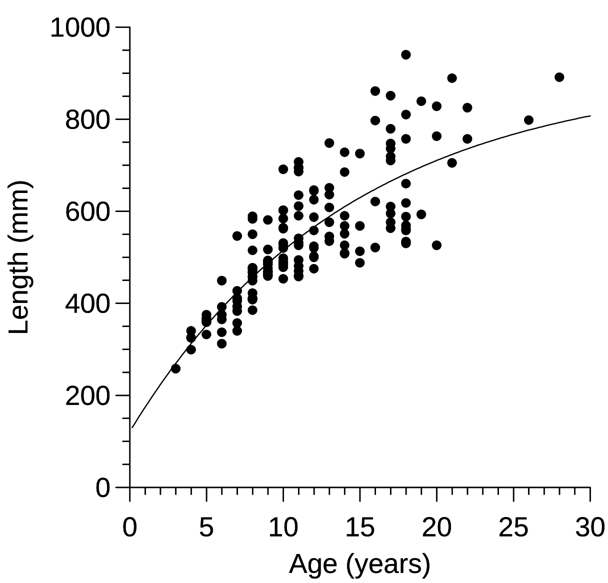
>MODEL MM = LINF*(1-EXP(-K*(INCREMENTS-T0)))
>LOSS = (LOG(MM)-LOG(ESTIMATE))^2
>ESTIMATE / GN START=1000,0.2,0 ITER=100

 Iteration
 No.      Loss       LINF         K            T0
   0 0.276520D+01 0.975935D+03 0.596644D-01 -.266393D+01
   1 0.275182D+01 0.966696D+03 0.596644D-01 -.266444D+01
   2 0.274968D+01 0.933659D+03 0.642675D-01 -.237629D+01
   3 0.274741D+01 0.925588D+03 0.659757D-01 -.228515D+01
   4 0.274686D+01 0.906224D+03 0.692523D-01 -.210613D+01
   5 0.274660D+01 0.904688D+03 0.696993D-01 -.208739D+01
   6 0.274660D+01 0.902836D+03 0.700458D-01 -.206950D+01
   7 0.274660D+01 0.902823D+03 0.700500D-01 -.206933D+01
   8 0.274660D+01 0.902823D+03 0.700501D-01 -.206933D+01

Dependent variable is MM
Final value of loss function is  2.746597006

                                                      Wald Confidence Interval
Parameter         Estimate       A.S.E.    Param/ASE        Lower < 95%> Upper
 LINF          9.02823E+02  1.05965E+02  8.519998227  6.93446E+02  1.11220E+03
 K             0.070050062  0.019584828  3.576751455  0.031352294  0.108747831
 T0           -2.069325536  1.090872632 -1.896945138 -4.224786719  0.086135647

Asymptotic Correlation Matrix of Parameters
                      LINF            K           T0
 LINF          1.000000000
 K            -0.980315198  1.000000000
 T0           -0.852592182  0.933416039  1.000000000
```



Reviewer Number 3.

Barry Hansen,

Overall, it is apparent that a great deal of work and effort has gone into this assessment. I realize that there is a great deal of information that is left-out because of the need to maintain a concise report and certain types of information are very difficult to obtain. I have gone through and made comments on each section and then attempted to address the questions at the back. I think that the fisheries biologists at both the CSKT and MFWP should be commended for this adaptive management approach to this problem.

Bull trout section:

There are a few pieces of information that would help me better evaluate the data.

(1) A little more information regarding the important bull trout spawning areas. The redd counts are for the Middle and North Fork of the Flathead River. Are those your index tributaries (mentioned in the juvenile count graph)? More information regarding what proportion of the streams with spawning bull trout populations are monitored (for each redd counts and juvenile abundance). For example, 5 index streams to give us information on 50 spawning streams?

(2) Do all index streams essentially have the same trend? Is this trend dominated by 1 or 2 of the 5 index streams, or are they all behaving the same way?

(3) Is there a way to calculate error bars for the redd counts and abundance estimates? If so, then we could have a sense of how certain we are that redd counts fall above the secure level and we have a sense of the probability of detecting trends.

(4) If you just look over the time period of the plan (2000- 2005, redd counts are down 2003-2005 and juvenile abundance is low 2004-2005). Bull trout are possibly stable (although difficult to be sure), but not doing particularly well (there is not strong evidence that they are doing better than when they were listed based on some of this data).

Westslope cutthroat section:

(1) Given that your stream surveys are some of the most reliable data for cutthroat (compared with angler catch and gillnetting – not useful for understanding trends), why didn't you provide it? That would be the data to include versus the other indices. Right now it is impossible to really evaluate the conclusion that westslope numbers are stable.

(2) Hybridization is a large threat to pure populations along the Flathead River system. So even though, the abundance of fish in streams is not necessarily changing, they are no longer pure populations.

    a. Given these trends, are the fish currently sampled in the lake typically hybrids? Given the hypotheses from previous work (Hitt, Boyer, Allendorf et al.) that hybrids are more likely to migrate/stray, you may expect the number of fish moving through the lake to increase with hybridization (and or those that currently move through lake to be dominated by hybrids).

    b. Given there are 15 streams with cutthroat population information and hybridization information… Can you use your data to address: (1) Do you see differences in population trends pre and post-hybridization? Is there more or less annual variation? (2) Do you see any interactions with brook trout and hybridization? Are hybrids more, less, or not different in their ability to co-exist with brook trout?

Do lake trout control bull trout?

(1) The reversal in catch rates of lake trout and bull trout could be a function of indirect effects associated with *Mysis* and not direct associated with their direct interaction. The ubiquitous pattern of similar reversals seen across western Montana with and without *Mysis* support the argument better that your first argument. I would combine them into one.

(2) It is hard to know how to evaluate anecdotal angler accounts. Anglers who make a living on the lake (commercial fishers, guides, etc) that tend to keep records, etc can be very good, reliable sources, but the reliability of other local knowledge is difficult to assess.
(3) Diet studies and bioenergetic models help put a number on consumption of bull trout by lake trout and I like the comparison to the Staples analyses, but to really understand the impact of that number we need to evaluate how does that consumption of subadults compare to the bull trout population? Is that 2% or 25% of the subadults produced? Also, do you know which streams have individuals moving into Flathead Lake, essentially how many populations are influenced by this consumption? Are those populations composed of fluvial, adfluvial and resident fish or because of the hydrology and habitat constraints are there few/no resident individuals?
(4) The fourth and first argument for lake trout control over bull trout are essentially the same and could be condensed into one.
(5) Alternatives: the report states that there are numerous examples of lake trout and bull trout living in sympatry for many decades. Unfortunately there are no citations associated with this statement. I would suggest that the authors list these systems and possibly how they are different from the published examples in the contrary. For example, do they appear to both persist where there more extensive stream networks? When discussing different streams and their relative recovery, it would be very interesting to know about relative proportion of different life history forms – do all fish leave these streams (no resident fish)?

Lake trout indicators

(1) The relative abundance of lake trout per sinking net is going to have a high variance and difficult to say a whole lot. Two things can influence gill net catch rates given their size selectivity– both changes in total population numbers and changes in size structure. One consideration that may come up is that if gill nets catch fish of a particular size and age, how do decreasing growth rates over this time period (1996-2005) change the number of age classes vulnerable to the nets? If this increases the age range and % of the population vulnerable to the nets then what does a stable catch indicate in light of these population changes?
(2) When Beauchamp did his modeling, how many *Mysis* were consumed by lake whitefish compared to lake trout? Why is lake trout the only considered species when discussing the *Mysis* trend?
(3) Angler harvest of lake trout (Figure 12) being constant isn't a great indicator since the fishery is changing so much (but possibly CPUE over a known group could be). Given that the CPUE per angler is increasing, this could indicate that more people are getting better at fishing for lake trout than before. Now that there are derbies with $$ associated with catching them, there is incentive to increase catch efficiency or for the better anglers to participate in the lake trout fishery.
    a. In your creel surveys is there a subgroup that you could separate out that has been fishing for lake trout for years and look at their CPUE to try to avoid this issue?
(4) Change in length at age is compelling.
(5) Although all indices have problems, I see no indication that lake trout populations are decreasing. It is difficult to know if they are stable or increasing.

Indicators that current exploitation is moderate and sustainable

(1) Is there a relationship between mortality rate and harvest? Given that you only have estimates from 2002 and there is not much variation from 2002-2005 and you may not see a trend.
(2) Does the fact that mortality rates are consistent across years imply that they are accurate? Not necessarily unless you relate it to the fact that harvest (or natural mortality) hasn't changed very much so that implies consistency in the procedure (but you could still have a bias).
(3) The fact that the mortality rates are consistent doesn't necessarily imply that the population is subject to moderate and sustainable exploitation. But, the relatively low level of the estimate might, if you compare it to other systems and the magnitude of mortality rates that lake trout populations can typically sustain.

Changes in length of maturity

(1) Was there any change in survey design, procedure, or training of personnel between 2000 and 2001? The large shift between 2000 and 2001 is difficult to explain, shifts in life history are often slow unless there is strong selection pressure.

Compensation

(1) Similar to the bull trout model, you would want to know which life history stage is the most sensitive when examining population growth rate? I would bet that changes in egg production are not that important. It would be worth simulating the different concerns regarding compensation and seeing which ones really matter. Given the size range of the lake trout eating bull trout, if high mortality rates of lake trout subadults can be maintained, it may still be worth it.

Past efforts

(1) Although lake trout harvested during derbies has continued to increase, there are no changes to total harvest (2002-2005). Why? Doesn't this demonstrate a serious problem with the current management strategy in attaining any goal associated with increased harvest?

Chances that lake trout would increase bull trout?

(1) It is difficult to look at where fish are captured and assume that you have information regarding where they were feeding. Lake trout movement rates and distances in many lakes are pretty large (compared with digestion rates).
(2) As bull trout recover, one might expect their encounter rates with lake trout to increase, as well as consumption rates of bull trout by lake trout. This could hinder rates of recovery.

Answers to the questions

(1) ***General Trends, which pieces of information are most useful?***

Bull trout: redd counts and juvenile surveys
Lake trout: changes in age structure, life history changes, population estimates
Westslope trout: stream survey data not reported here

(2) Factors controlling bull trout abundance

Coal Creek: I do not know the index streams at all. Stream habitat limitations are the most likely explanation for the lack of recovery in Coal Creek. If there were differences in size or timing of outward migration to the lake of subadult individuals from Coal Creek, then one may expect their survival would be different Is there a difference in the proportion of the population of migratory versus resident fish in these creeks? If Coal Creek has low flow, poor winter habitat, etc. and all fish are migrating into Flathead (vs. other creeks) this could also influence recovery.

Elimination of bull trout: I would like to hear more about systems where they are co-existing. Maybe in areas with large, healthy stream networks bull trout can sustain their populations with large proportions of resident fish. Or in very large lake systems with a diversity of prey and lake trout have a preferred prey item available (e.g., if there are lots of kokanee available, lake trout may not prey switch that often and vulnerable bull trout may not experience high predation rates). In systems where they co-occur do lake trout have diverse diets?

I would want to know more about the stream networks and the current population before really having any confidence in my prediction. Given my current knowledge, my ***guess*** is that bull trout will survive at low population levels for a while (lowering their long term chance of survival) with a medium likelihood of extirpation over 100 years or so. Of course, I buy house insurance- a low probability of a catastrophic event drives me to be willing to be conservative and put in money up front to plan or try to avoid it.

Given how difficult it is to deplete lake trout. Has anyone taken the current model of bull trout in the region and modeled the current population trend, the likely impacts on bull trout population growth from habitat alteration, brook trout, and lake trout to project whether lake trout are having the largest impact on bull trout populations and what is a decent secondary plan to maintain bull trout populations if nothing can be done about lake trout (what would have to be done to improve habitat, remove brook trout, etc.)? If controlling lake trout isn't the biggest bang for your buck then other options are useful. In evaluating this, I would argue that a larger landscape perspective is important, where else are these Flathead Lake fish going? What is the influence of dispersal across the larger landscape?

Growth of lake trout

I don't know about the magnitude but other studies have shown compensatory changes in growth rates of lake trout.

Increases in size of maturity are predicted in life history theory where the trade-off of getting larger to begin to reproduce outweighs the potential for not surviving to reproduce (and increase in generation time). So, this implies to me given the poor condition of the fish – there are large benefits to increasing size before maturing (given the exponential increase in eggs with fecundity – that is easy to imagine on a per capita basis but also it may have something to do with the size-structure of the prey base – more energetically beneficial prey available to these larger fish?). But to me this also means that adult survival must be very high. What is most surprising to me is the rate of change! This implies strong selective pressure (often seen with strong fishing pressure, but the recovery of the life history traits without fishing pressure is thought to take much longer).

Uncertainty in harvesting lake trout:

Overshoot our goal?

Overall, I am not worried given the current trends and the likely compensatory responses that will likely occur (increase in recruitment and decrease in cannabalism). If that is the case, I think that managers would be able to respond.

Why do I think that managers could respond before collapsing the lake trout fishery?

(1) If you know your age curves and your slot limit over overlaps the ages that you monitor with the gill net surveys (which is currently true I think) then you will see an impact on the age structure first from your gill net survey.

(2) If you look at the ages being harvested, there are large fish not harvested with many years of reproductive left to help maintain recruitment (even if you see an impact on the age structure). Essentially you have a large amount of momentum in the system with long-lived fish.

Increases in Mysis? I don't know the relative contribution of lake whitefish (or of any species found deeper), there is the potential to have an impact on the zooplankton similar to the initial years.

Will decreasing the population increase the lake trout population?

Quite possibly given the poor condition, late age of maturity, etc. of the current lake trout population. There may be an increase in the short-term but I would like to see what the potential to contain that is through modeling simulations before using that as reason to do nothing.

Otolith aging: Since the ages were right next to the pictures, they definitely influenced my readings. Next time I would recommend you have reviewers age the otoliths without any information regarding estimated age or length. The blind reader approach provides data that would not be influenced by previous readings at all.

Thanks! It is very interesting!

I hope that these comments are useful.

Reviewer Number 4.

Flathead Lake 5-year Review

Sept 16, 2006

1. General Comments

Thank you for the opportunity to review your report on the management plan for Flathead Lake. It is indeed a very interesting and important experiment. It is also rather unique – which makes it more difficult to interpret the response to “high harvest” of lake trout.

I denote “high harvest” in parentheses because my immediate reaction is that the harvest does not appear to be very high. As you note in the report, sustainable yields higher than 0.7 kg/ha have been observed in several lake trout lakes. Estimates of maximum sustainable yield used by Shuter et al (1998) are in this range, so this harvest level seems rather low if your objective is to curtail (or reduce severely) impacts of lake trout on the fish community.

In Ontario, we have been conducting a lake trout harvest experiment on one small lake (Squeers Lake) by harvesting 2 kg/ha annually. The experiment has been in progress for 20 years. We predicted the population could not sustain this level of harvest, but the population has proven to be more resilient than expected. Population size (> 6 years old) has declined approximately 3-fold. Angling CUE (fish per angler-hr) has not changed, although mean fish size has declined. Density-dependent changes in growth, maturation and relative fecundity have been observed. A report describing these responses is being prepared by the office that conducted this experiment and I will send you a copy when it is available. I have mentioned that study mainly to emphasize that a higher lake trout harvest may be needed to realize your goal of reducing lake trout impacts.

Your report does not provide any information about the sizes of lake trout harvested by anglers and captured by the index netting surveys. This information is useful for understanding the response. Reading between the lines, I assume that mean size of lake trout has declined. For example, I assume Fig 12 reports harvest in terms of fish weight and conclude that harvest weight per angler day has not changed greatly. Yet, Fig 13 indicates angling CUE (#fish/hr) has increased. The discrepancy suggests that mean size of fish captured has decreased - probably because the population has shifted towards smaller body size. Reporting mean size of lake trout in the creel and gillnets would help remove this guesswork.

Analysis of growth is difficult because in the presence of Mysis the lake trout population seems to consist of two morphs: a small bodied sub-population that asymptotes at 600 mm and a larger bodied sub-population that asymptotes at 900 mm. (Fig 14 is hard to read, but I suspect that variance in length at age is higher now than it was prior to the arrival of Mysis.) This phenomenon is common in lake trout lakes (especially when the abundance of coldwater forage fish is limited): one sub-population specializes on invertebrates and attains a relatively small asymptotic size while another sub-population becomes piscivorous and attains a larger asymptotic size. The difference in asymptotic size is expected because as lake trout grow their diet must shift towards larger food particles to sustain growth efficiency. In lakes where coldwater forage species are not present, the piscivorous life-style is supported by cannibalism; in Flathead Lake piscivory is supported by a mixture of coldwater fish species, including lake trout (see Fig. 11). From Fig 11 it is clear that Mysis (and other invertebrates) largely disappear in the diet of fish larger than 625 mm.

This interpretation of the size-at-age data shown in Fig 14 implies that changes in lake trout growth (and maturation) may be related to a change in life-style (i.e., a shift in the proportion of fish that specialize on fish or invertebrates). Prior to the arrival of Mysis, the prey availability supported a low density of piscivorous lake trout with high growth rate (i.e. 749 mm at age 9). After Mysis have become established for some time (i.e. 2005), lake trout density is high and growth rate is much lower (478 mm at age 9). In 2005, the majority of age 9 fish are feeding mainly on invertebrates. In contrast, age 9 fish during the early 1980s were probably feeding on fish. I speculate that the current abundance of forage fish can support only a small population of fish that become piscivorous; the rest of the population never transcends beyond a trophic level that sepcializes on Mysis. I expect that most of the ‘old but small’ fish (i.e. > 10 years and 450 mm) are mature and that they become mature at a smaller size than the ‘old but large’ fish (i.e. > 10 years and 600 mm).

The rapid change in size and age of maturity in recent years is baffling. More information about size and age of maturity from earlier time periods would be useful, but I suspect it is not available. Also, Fig 31 should be corrected (it is supposed to show change in age of maturity) and the statement on page 35 (age at which female fish reach full maturity) should be clarified – what is full maturity? Is it the same as age at 50% maturity? Regardless of this confusion, the point made is that age of maturity is increasing very rapidly (stepping up by almost one year each year – from 6 to 11 over a period of 8 years). I have never seen such rapid change. It makes me wonder whether the effect is due to a change in the relative abundance of 2 sub-populations which have different maturity schedules. For example, if the piscivorous sub-population matured late and the invertivorous sub-population matured early, age of maturity would increase if the piscivorous sub-population became more dominant (or if sampling bias shifted in favour of this sub-population). It would be interesting to compare current maturation schedules (for age and size) to those that existed in the early 1980s when the population was probably dominated by a piscivorous sub-population.

2. Response to Questions

1. I favour trends based on the gillnet surveys, but other methods are useful checks providing their cost is low. If costs of other methods are high, then I would favour more intense gillnet sampling.

2. Fig 5 is quite convincing that a gillnet survey can document large changes in abundance. For example, compare results in the early 1980s to those from the recent period. Trends during the recent period are not detected, but this is not surprising given that 1) harvest is not very intense (i.e. a change may not have occurred) and 2) the time lag to observe effects is long for a late-maturing long lived species. An earlier indication of change could be obtained by focussing on small (i.e. young) fish. “Number per net’ is not very informative by itself; reporting mean and median size of fish captured helps to describe changes that may be occurring.

3. No comment.

4. No comment

5. I have not observed such large changes in size at age, but I have little experience with lake trout populations where such dramatic changes in abundance have occurred. Based on my knowledge of other species (and some bioenergetics modelling) I think that two-fold changes in growth rate (prior to maturation) are within the expected range of a density-dependent growth response for populations experiencing large changes in food availability.

6. No comment

7. I expect annulus formation depends on climate. I will consult with local experts about this point and get back to you. I will also seek age interpretations of the material you provided.

8. Increased length at maturity? See comments above.

9. The answer depends on the lake trout exploitation target you are seeking. I do not think that current exploitation levels are excessive given the nuisance factor associated with lake trout. In southern Ontario, your fishery (CUE > 0.5 fish/hr) would rank as exceptionally good – we typically see angling catch rates that are much lower (i.e. 0.15 fish per hour). Admittedly, this low value is a result of historical over-exploitation and other stresses and, in many cases, our management efforts are aimed at rehabilitating lake trout and offering higher quality fisheries. Given the exceptional fishing that is currently available in Flathead Lake, I think there is room for reducing lake trout abundance further and still offering a stable high quality fishery.

10. No comment.

11. I cannot answer this question based on the summary because it does not provide a description of the stock-recruitment relationship observed so far. If you asked me what direction further experiment should take, I would definitely recommend higher harvest to place additional stress on lake trout. This action will be more informative than the status quo and I believe it can be taken without sabotaging the lake trout fishery.

Reviewer Number 5.

Page	Section	Comments
12	Fig 1	Unsure if you can reasonably conclude that the bull trout population is currently “stable” from redd count data. It appears there have been oscillations since the *Mysis* effect (1992) and the data do not support a conclusion of stability. Particularly since there was a decline from 2000 to 2003 and only two years of data following 2003.
13	Fig 3	Need a clear legend to determine difference in colors of bars and what these color differences mean.
13	Staples	Staples et al. did not conclude the population was stable, rather they concluded that the population’s future was still uncertain and warranted special vigilance. They also concluded that the population was near a relatively low threshold and that warranted concern.
14	4)	You should cite the Hitt et al. paper for rate and potential cause of hybridization. I believe hybridization risks are relatively higher than you portray and need to be addressed more aggressively.
17	Alt Interp	I believe the alternative explanation is likely the more plausible explanation because it actually brings more research to bear on the issue. The potential synergistic effects of high fine sediments in the streambed and lake trout may be what caused the decline, but hard to tease these two effects apart from the data. I think that high fine sediments were recorded in the late 1980’s, but that needs to be verified.
18	Alt Interp	I do not think it is too plausible that survivals to adults after the juveniles leave the streams is different between the two streams. No evidence that juveniles from different streams move to different areas of the river or lake or move at different rates; however, this has not been explicitly tested very well.
19	para 2	Suggest “We **have** follow**ed** a stratified … in the fall **since 1998**, ….
21	top	Is it possible that predation by lake trout on *Mysis* has kept *Mysis* numbers lower than they would have been without lake trout? If so, there might be a benefit to other planktivorous species, such as cutthroat trout? A possibility worth considering.
21	Fig 12	This graph is confusing and appears contradictory. Harvest appears relatively constant from 2002 to 2004, but catch rates increase between 2002 and 2003. Either there are fewer anglers (less pressure) from 2002 to 2003 and 2004, or more lake trout are being released in 2003 and 2004. This difference is important because if more lake trout are being released, then a mandatory keep regulation might have an effect on the lake trout population.
	AGE	To validate age interpretations you should not have provided previous estimated ages, but allowed each observer to make an independent age interpretation. I’m afraid providing *a priori* age estimates will severely bias any validation results you compute.